Surface pion condensation in finite nuclei

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The pion is the mediator of nucleon-nucleon interaction. It plays the central role in hadron physics, in which the chiral symmetry and its spontaneous breaking, and hence the pion as its Goldstone particle, are the essential features for the description of various phenomena. In nuclear physics, however, we tend to describe nuclear structure by using the shell model without much emphasis on the role of the pion. This is because the pionic correlations are effectively contained in the central and spin-orbit interactions in the nuclear model space. Therefore, when the role of the pion is explicitly necessary, it is introduced as the perturbation for the description of the phenomenon.
Recently, there has become possible to solve few-body to several-body problems ($A \leq 10$) without referring to the single particle orbits due to the computer power and the numerical technology. The results compare extremely well with experiments. Furthermore, the calculated results demonstrate a dominant role of the pion in these nuclear systems. Recent experiments for spin-isospin nuclear responses demand also the important role of the pion.
Hence, we are motivated to treat the pion explicitly in the mean field theory for the description of medium and heavy nuclei. We take the relativistic mean field theory (RMF) and include the pion terms. We have to break the parity of single particle states in nuclei in order to include the finite pion mean field. This needs the concept of phase transition, which should be referred as pion condensation. Here, we would like to emphasize that the pion is a pseudoscalar particle and hence needs the modulation of the spin-density, which costs energy in nuclear matter. However, in finite nuclei, there exists the nuclear surface, which naturally provides the necessary density modulation without the cost of the energy. Hence, we name the occurrence of the finite pion mean field as surface pion condensation.
We demonstrate the actual occurrence of the finite pion mean field and its mass dependence [1]. We show also the qualitative consequence of the finite pion mean field on various observables.

References

[1] H. Toki, S. Sugimoto and K. Ikeda, nucl-th/0110017.